Elementary-Particle Propagation Via 3-Scale "Towers of Quartet Rings" Within a Dyonic History Lattice

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Disclaimer

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ABSTRACT

Massless elementary-particle propagation is represented historically (cosmologically) through 3-scale "towers of quartet rings" within a lattice of magneto-electrodynamically communicating "pre-events". The lightlike intervals within a ring of 4 pre-events (discrete "closed string") display transverse GUT-scale and longitudinal "particle scale". The lightlike (longitudinal) spacing between successive rings of a tower is at Planck scale. Ratio between GUT scale and Planck scale relates quantum-dynamically to elementary magnetic charge. Permutations of a ring quartet, in conjunction with Lorentz-group representations, control elementary-particle quantum numbers.

I. Introduction

A historical quantum cosmology, based on lattice coherent states labeled locally by "pre-event" chains, has been formulated[1]. The constraints defining "history lattice" include causal (i.e., lightlike) magneto-electrodynamic (MED) pre-event connections. [2] The present paper offers historical representation of massless elementary-particle propagation through a special history pattern describable as a "tower of magnetically- confined pre-event quartet rings" that display both GUT scale and a much larger "particle scale". Spacing between successive rings is at a third, more fundamental, local scale that historical cosmology identifies with Planck scale[1]. Ratio between GUT and Planck scales will here be related to elementary magnetic charge.[2]

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[1]This paper ignores a global scale, hugely larger than any of the 3 scales discussed here (although smaller than local age), that relates to distinction between "present" and "past"[1].

[2]Magnetic charge is screened at scales above those characterizing quartet rings while localized energy, defined through towers, is devoid of meaning at lower scales. Historical cosmology thus precludes "magnetic charge carried by matter."

Although the present paper does not address historical representation of interaction *between* elementary particles, many of the principles invoked here are relevant to particle- interaction (e.g., "pair of pants") pre-event patterns – which may be called "local events" in contrast to "pre-events." Our concluding section calls attention to one such principle: the continuity, along a history-chain segment, of electric charge and certain other discrete "quantum numbers".

A tower-propagator history pattern might be described as a "closed string moving in spacetime", but the "string" is discrete (comprising 4 pre-events with GUT-scale spatial spacing and particle-scale temporal spacing) and its "motion" is discrete (in Planck-scale steps). Despite history-lattice discreteness, the (continuous) Lorentz group plays a central historical role, discreteness being reserved to Lorentz invariants. Local physics blends into global cosmology within a discrete history that relies on the Lorentz group at all scales. Local Lorentz covariance, while not an exact feature of historical cosmology, is approximately valid for velocities currently accessible to physical observation.

II. Towers of Interleaved Pre-event Ring Quartets

Reference (1) prescribes a "history lattice" with a longitudinal "chain" structure. Matter representation requires further a transverse "ring" structure. Steps along the chain and intervals around a ring are both lightlike. The longitudinal chain step has a *fixed* interval δ in pre-event age ("age" is defined below). It has been conjectured that the value of δ, once meaning for the gravitational constant has been identified within historical cosmology, will turn out to be on Planck scale. The fundamental parameter δ establishes a "smallest" scale for historical cosmology.

Although longitudinal chains comprise Hubble-scale closed loops, to the extent that each longitudinal loop contains a number of pre-events ($> 10^{60}$ for loops passing close to our region of the universe) much larger than the pre-event number building a typical propagator tower (particle collision times are presumed small on Hubble scale), this paper will disregard the compactness of (longitudinal) history-chain segments. Such a posture conforms to physics disregard of distinction between "present" and "past".

The number of pre-events in a "transverse ring" is exactly 4 with each member of a pre-event ring quartet belonging to a *different* segment of the (longitudinally-looping) history chain. The term "ring" means the 4 pre-events are cyclically ordered. *Adjacent* pre-events around a ring have *opposite − sign* magnetic charge and lightlike spacetime separation (they "communicate", with alternation of advanced and retarded connections). In the ring quartets building propagator towers, the magnitude of any pre-event magnetic charge is the elemental $\tilde{e}$; passing around a ring, magnetic-charge sign alternates. "Opposing" pre-events ("across the ring" from each other) share not only the same magnetic charge (both $+\tilde{e}$ or both $-\tilde{e}$) but the same age. Opposing pre-events do not (directly) communicate with each other, being spacelike separated. The mean spatial separation between opposing pre-events will be found

to exhibit GUT scale.

The magnitude of the age difference (an integer multiple of δ) between magnetically-positive and magnetically-negative pre-events within a quartet is common to *all* rings within tower (matter-propagation) history patterns. This difference will be designated by the symbol δ'. Section III will associate the term "particle scale" with δ' and argue that δ' must be huge on GUT scale in order to achieve the approximate local Lorentz covariance of particle physics. A matter-representing ring quartet exhibits GUT scale spatially and particle scale temporally, with Planck scale characterizing the spacing between successive rings building a tower.

According to Reference (1), *all* history (whether tower or otherwise) occupies the interior of a forward big-bang lightcone. Such an idea first appeared in the cosmology of Milne.[5] Spacetime location of Pre-event n is given by a positive-timelike 4-vector $\mathbf{x}_n$ prescribing pre-event *displacement* from lightcone vertex. Pre-event age τ_n is the Lorentz magnitude of $\mathbf{x}_n$. (Pre-events in *our* neighborhood have ages of order 10^{10} years or $\sim 10^{60}$ in units of δ).

Let us designate those 4 pre-events building a ring quartet Q by the index pair (Q, i) with i cyclic – i.e., i$\pm$4 is the same as i. A pre-event pair (Q, i) and (Q, i $\pm$ 1) are "adjacent"; their lightlike separation means

$$(\mathbf{x}_i{}^Q - \mathbf{x}_{i\pm1}^Q)^2 = 0, i = 1, 2, 3, 4. \tag{1}$$

A pair (Q, i) and $(Q, i \pm 2)$ are "opposing", with spacelike separation:

$$(\mathbf{x}_i{}^Q - \mathbf{x}_{i\pm2}^Q)^2 = -(d_-^Q)^2, i = 1, 3 \quad , \tag{2}$$

$$(\mathbf{x}_i^Q - \mathbf{x}_{i\pm2}^Q)^2 = -(d_+^Q)^2, i = 2, 4. \tag{3}$$

The notation in (2) and (3) reflects assignment of negative magnetic charge to i = 1, 3 and positive magnetic charge to i = 2, 4.[3] The (length dimension) spatial parameters $d_\pm^Q$ prescribe the "shape" and "size" of the ring.

The set of four 4-vectors $\mathbf{x}_i^Q$, comprising 16 parameters, satisfy the following conditions on the 10 Lorentz invariants, $\mathbf{x}_i^Q \cdot \mathbf{x}_j^Q$:

$$\mathbf{x}_1^Q \cdot \mathbf{x}_1{}^Q = \mathbf{x}_3{}^Q \cdot \mathbf{x}_3^Q = (\tau_-^Q)^2 \quad , \tag{4}$$

$$\mathbf{x}_2^Q \cdot \mathbf{x}_2{}^Q = \mathbf{x}_4{}^Q \cdot \mathbf{x}_4^Q = (\tau_+^Q)^2 \quad , \tag{5}$$

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[3]Electric charge and other discrete quantum numbers render distinct all 4 values of i.

$$\mathbf{x}_1^Q \cdot \mathbf{x}_3{}^Q = (\tau_-^Q)^2 + \frac{(d_-^Q)^2}{2} \quad , \tag{6}$$

$$\mathbf{x}_2^Q \cdot \mathbf{x}_4{}^Q = (\tau_+^Q)^2 + \frac{(d_+^Q)^2}{2} \quad , \tag{7}$$

$$\mathbf{x}_i^Q \cdot \mathbf{x}_{i\pm1}^Q = \frac{\left(\tau_+^Q\right)^2 + \left(\tau_-^Q\right)^2}{2}, \quad i = 1, 2, 3, 4. \tag{8}$$

Thus all 10 invariants are determined by the 4 positive parameters, $d_\pm{}^Q, \tau_\pm^Q$. According to Section III below, the length parameters $d_\pm^Q$ are not fundamental constants and relate quantum-magneto-dynamically to the quartet of pre-event impulses.

There remain six "external" ring degrees of freedom – the parameters of a Lorentz transformation that leaves invariant the 10 inner products $\mathbf{x}_i^Q \cdot \mathbf{x}_j{}^Q$. Defining the ring-center (positive-timelike) 4-vector

$$\mathbf{X}^Q \equiv \frac{1}{4}(\mathbf{x}_1^Q + \mathbf{x}_2^Q + \mathbf{x}_3^Q + \mathbf{x}_4^Q), \tag{9}$$

with magnitude (center age)

$$\tau^Q \equiv \{\frac{1}{2}[(\tau_+^Q)^2 + (\tau_-^Q)^2] + \frac{1}{16}[(d_+^Q)^2 + (d_-^Q)^2]\}^{\frac{1}{2}}, \tag{10}$$

3 Lorentz boost parameters spatially locate ring center with respect to big-bang vertex, [4]while 3 rotation parameters orient the ring in its center Lorentz frame. Counting center age, a ring has a total of 7 "external" degrees of freedom. (When *different* rings combine into a larger history pattern, such as a tower, some of the separate-ring external degrees of freedom become "internal" to the larger pattern. The *total* number of external degrees of freedom for *any* pattern is 7, corresponding to a Lorenz transformation plus an age.)

The coordinates of any quartet provide a complete basis. Employing the notation

$$\mathbf{x}_{ij}^Q \equiv \mathbf{x}_i^Q - \mathbf{x}_j^Q, \tag{11}$$

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[4]Designating the 3 ring-center boost parameters by a 3-vector $\vec{\beta}^Q$, spatial location of ring center is

$$\vec{X}^Q = \tau^Q \frac{\vec{\beta}^Q}{|\vec{\beta}^Q|} sinh|\vec{\beta}^Q|.$$

a convenient basis comprises the two spacelike 4-vectors $\mathbf{x}_{24}^Q$, $\mathbf{x}_{31}^Q$ and the two timelike 4-vectors $\mathbf{X}^Q$ and

$$\mathbf{U}^Q \equiv \frac{1}{2}(\mathbf{x}_2^Q + \mathbf{x}_4^Q) - \frac{1}{2}(\mathbf{x}_1^Q + \mathbf{x}_3^Q), \tag{12}$$

with magnitude

$$d^Q = \frac{1}{2}[(d_+^Q)^2 + (d_-^Q)^2]^{\frac{1}{2}}. \tag{13}$$

We may render $\mathbf{U}^Q$ *positive*-timelike by requiring $\tau_+^Q > \tau_-^Q$.

The spacelike pair $\mathbf{x}_{24}^Q$, $\mathbf{x}_{31}^Q$ are orthogonal not only to each other and to $\mathbf{U}^Q$ but to $\mathbf{X}^Q$. Only the timelike basis pair $\mathbf{X}^Q, \mathbf{U}^Q$ fails to be orthogonal. The two spacelike directions may be called "transverse" and the two timelike directions "longitudinal". In the proposed basis,

$$\mathbf{x}_1^Q = \mathbf{X}^Q - \frac{1}{2}\mathbf{U}^Q - \frac{1}{2}\mathbf{x}_{31}^Q,$$

$$\mathbf{x}_2^Q = \mathbf{X}^Q + \frac{1}{2}\mathbf{U}^Q + \frac{1}{2}\mathbf{x}_{24}^Q, \tag{14}$$

$$\mathbf{x}_3^Q = \mathbf{X}^Q - \frac{1}{2}\mathbf{U}^Q + \frac{1}{2}\mathbf{x}_{31}^Q,$$

$$\mathbf{x}_4^Q = \mathbf{X}^Q + \frac{1}{2}\mathbf{U}^Q - \frac{1}{2}\mathbf{x}_{24}^Q.$$

The reader may find it a useful exercise to verify the relations (1), (2), (3), through (14) given (13). For subsequent use we also record here the relation

$$\mathbf{X}^Q \cdot \mathbf{U}^Q = \frac{1}{2}[(\tau_+^Q)^2 - (\tau_-^Q)^2] + \frac{1}{8}[(d_+^Q)^2 - (d_-^Q)^2], \tag{15}$$

that is deducible from formulas (4).....(8).

There is a lightlike displacement from Pre-event (Q, i) to the following (older, by the increment δ) pre-event along its history-chain segment. A unique set of 4 displacements, connecting a pair of longitudinally-adjacent quartets within a tower, is determined by requiring that quartet orientation and "shape" remain unchanged throughout a tower, and that displacement of quartet center be orthogonal to the two (fixed) orthogonal transverse spacelike directions. By "shape" is meant the *ratio* of the two transverse distances d_+^Q/d_-^Q. A tower is thus characterized by the orientation

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and shape of *any* of its constituent ring quartets. The direction of tower "axis" corresponds to propagation direction. The magnitude d^Q varies from one quartet to the next as the age of each pre-event increases by the increment δ, but in a "mature" ("dilute")region of the universe, where $\tau \gg (\delta'/\delta)^2 \delta$, the fractional variation is of order δ/τ. For purposes of mature-region "physics" (as opposed to "cosmology"), a tower is characterized by a *single* "width" d. Quantum fluctuation of d is nevertheless important.

Notice that, with $\delta' > \delta$, age spacing between magnetically-positive and magnetically-negative pre-events within the same ring quartet is larger than spacing between same-sign pre-events of (longitudinally) adjacent quartets. There is *interleaving* of ring quartets within a tower. The electrodynamic considerations of the following section indicate a value of δ' huge compared to δ.

Collision times (age intervals between successive collisions of elementary particles) are meaningless if smaller than δ' because individual ring quartets are unsustainable. More generally, the tower history pattern is essential to the very meaning of "matter". Within historical cosmology, matter (localized energy) is only an approximate concept, meaningful at spatial scales larger than d and temporal scales larger than δ'. Extremely close to big bang where towers are unsustainable, localized energy loses significance.

III. Pre-Event Impulses Within a Tower

Each pre-event is endowed not only with a positive-timelike spacetime-location $\mathbf{x}_n$ but with a spacelike 4-vector impulse $\mathbf{q}_n$ and a positive timelike unit-magnitude charge 4-velocity $\mathbf{u}_n$ that is orthogonal to $\mathbf{q}_n$. In a tower, as this section will elaborate on the basis of Reference (2), charge velocities are longitudinal while impulses are transverse. Reference (2) prescribes history-lattice constraints that "causally" (and linearly) determine the impulse at a pre-event from the electric and magnetic charges and charge velocities at those *other* pre-events located on its lightcone. (Impulses, like spatial separations between pre-events, are subject to quantum fluctuation.)

Within a tower history pattern in a mature region of the universe, there is near MED cancellation from "sources" on that history-chain segment containing the pre-event whose impulse is being calculated. We concentrate here on MED interactions within a *single* ring quartet, there being within a tower *no* lightlike-separated (i.e., "communicating") pre-event pairs that locate on different history-chain segments and *also* locate in different ring quartets. The interacting pre-event pairs within a ring quartet are those 4 pairs adjacent to each other around the ring. The impulse at any pre-event is generated by the charges of its two "ring neighbors", whose magnetic charge is of sign opposite to its own. Electric charge is less constrained. Each of the 4 history-chain segments may carry electric charge 0, $\pm$ e. (In Section IV, photon coupling to electric charge indicates that at least one of the 4 chain segments building a charged-particle tower carries zero electric charge.)

In a mature region of the universe, the displacement between centers of suc-

cessive quartets is nearly at maximum velocity – corresponding to massless-particle propagation. The success of Lorentz-covariant local field theories (such as QED) that make no distinction between charge and matter velocity (and no reference to a special frame) implies a tower charge velocity close to maximum; direction should be longitudinal. The unique longitudinal 4-direction "internal" to a quartet is that of $\mathbf{U}^Q$. In the absence of alternative we postulate for any charge velocity within quartet Q,

$$\mathbf{u}^Q = \mathbf{U}^Q/d^Q. \tag{16}$$

Such assignment implies spatial direction of $\mathbf{U}^Q$ in the direction of propagation (*not* in the spatially reversed diretion).

What is meant by a magnitude of charge velocity "close to maximum"? Cosmology provides an answer to this question through the special Lorentz frame belonging to quartet center. This frame, approximately shared by all history within a region small on the scale of τ^Q ("Hubble scale"), is the frame in which cosmic background radiation is approximately isotropic (analog of co-moving coordinates in standard cosmology).

In quartet-center frame,

$$\mathbf{X}^Q = (\tau^Q, \vec{0}), \tag{17}$$

$$\mathbf{U}^Q = d^Q(cosh\xi^Q, \vec{n}^T sinh\xi^Q), \tag{18}$$

where $\vec{n}^T$ is a unit 3-vector prescribing propagation direction and

$$cosh\xi^Q = \mathbf{X}^Q \cdot \mathbf{U}^Q/d^Q\tau^Q. \tag{19}$$

Referring to (15), we find in mature-region approximation,

$$cosh\xi \approx \frac{\delta'}{d}. \tag{19'}$$

In center frame, magnitude of charge velocity is

$$tanh\xi \approx [1 - (\frac{d}{\delta'})^2]^{1/2}. \tag{20}$$

"Close to maximum" thus means huge $\frac{\delta'}{d}$. The success of Lorentz-covariant models that tie charge velocity to matter velocity (and ignore the special Lorentz frame) requires a huge order of magnitude for δ'/d, with the age interval δ' establishing a scale that we optimistically call "particle scale", expecting eventually to connect δ'

with particle-physics data. Hugeness of $\cosh \xi^Q$ means that *all* longitudinal 4-vectors characterizing *internal* tower structure are "almost lightlike"; approximate Lorentz covariance for earth-based particle physics then becomes possible.[5]

With $\tilde{e} \gg e$, the largest contribution to the MED impulse at Pre-event (Q, i) arises from its magnetic charge interacting with the magnetic charges of its two neighbors. The prescription of Reference (2) gives, for magnetic impulse,

$$q_{i,\mu}^{Q,mag} = \frac{\delta \tilde{e}^2}{(d^Q)^3}(x_{i,i\pm2}^Q)_\mu, \tag{21}$$

the direction being "inwardly-radial" – *toward* tower central axis. (Note that all previous 4-vector relations in this paper have implicitly involved only *upper − index* 4-vectors.) Radial magnetic-impulse magnitude is

$$q_{\pm}^{Q,mag} = \frac{\tilde{e}^2 \delta d_{\pm}^Q}{(d^Q)^3}. \tag{22}$$

Magnetic "coulomb attraction" provides transverse stability for a tower of quartet rings [6].

Electric impulses proportional to $e_i e_{i\pm1,}$ being smaller than (22) by a factor of order $(e/\tilde{e})^2$, cannot undo tower stability even when "repulsive" (i.e., when outwardly-radial). There are no impulses proportional to $e\tilde{e}$, a product we expect to be constrained in a manner paralleling that discovered by Dirac[4], once quantum superposition of history is systematically addressed. This paper will not be systematic in such regard.

Formula (22) for the radial impulse, nevertheless, in conjunction with qualitative quantum considerations, suggests the order of magnitude of d^Q. When towers of different $d_{\pm}^Q$ are superposed, minimum fluctuation ("ground state")[7] is plausibly achieved by $d_{+}^Q = d_{-}^Q$, with

$$q_{\pm}^Q d_{\pm}^Q \sim \hbar. \tag{23}$$

Formula (22) then yields the estimate

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[5]Qualitative successes of primordial nucleosynthesis calculations[3] indicate that collision times remain meaningful at scales as low as 10^{-23} sec. An *upper* limit on δ'/δ in the neighborhood of 10^{20} is thereby set. Phenomenological considerations by Coleman and Glashow[6] indicate a *lower* limit for $\cosh \xi$ in the neighborhood of 10^{11}.

[6]Longitudinal stability is provided by persistence of electric and magnetic charges, along with other discrete indices, along any segment of the (looping) history chain.

[7]Such reasoning, applied to the ground state of hydrogen, correctly estimates the ratio of radius to period as $\sim (3e)^2/\hbar$.

$$< d^Q > \sim \frac{\tilde{e}^2}{\hbar} \delta \tag{24}$$

for "mean tower width".

Tower structure has now been characterized by 3 different scales – δ, δ' and $< d^Q >$. Largeness of $\tilde{e}^2/\hbar$ (assuming small fine-structure constant, with $e\tilde{e} \sim \hbar$) suggests association of mean d^Q with GUT scale. Propagator-towers within the history lattice, that is to say, have GUT scale mean transverse dimension [8]. A mean value of $\cosh \xi$ in the neighborhood of 10^{16} might then be compatible with $\delta'/\delta \sim 10^{18}$.

V. Conclusion

Although not pursued here, quantum superposition of *external* tower Lorentz parameters provides meaning for massless elementary-particle momentum and helicity via representations of the Lorentz group[9]. Choice of representation involves an 8-valued "sector index" (in addition to electric and magnetic charge) that is carried by each history-chain segment. Four of the 8 values, denoted in Reference (1) by $S_1, \bar{S}_1, S_2, \bar{S}_2$, are suitable for patterns of material history. The index interchanges $S_1 \leftrightarrow \bar{S}_1$ and $S_2 \leftrightarrow \bar{S}_2$ have a significance paralleling (local) "particle-antiparticle conjugation." The $1 \leftrightarrow 2$ interchange has a global significance. The outlook for historical cosmology depends on whether ring-quartet patterns of electric charge, spin and internal quantum numbers conform to the discoveries of particle physics. Permutation-group (S_4) analysis in conjunction with Lorentz-group representation must be undertaken.

The 4-remaining values of sector index, denoted $T_1, \bar{T}_1, T_2, \bar{T}_2$ in Reference (1), contribute to "nonmaterial" patterns of history that tentatively have been called "vacuum". Coupling of "vacuum" to material history is conjectured to suppress large-scale fluctuation of *past* material history. (Historical cosmology distinguishes "present" from "past", even though such a distinction has played no role in this paper.) "Many worlds"[7] i.e., material past histories that are distinct at scales far above particle scale – are not anticipated.

We conclude with superficial remarks about the notion that "a photon couples to electric charge." The general "pair of pants" pattern joins 3 towers with continuity of history-chain segments[10]. It is plausible that a photon ring quartet carries electric charges +e, −e, 0, 0, with e one-third the magnitude of charge carried by elementary electrons. The ring quartet of an elementary particle capable of emitting or absorbing

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[8]Alternatively one might say that "closed strings" of 4 pre-events have GUT-scale "radius". The dynamical considerations of the present section might be regarded as an estimate of "string tension."

[9]Fluctuation in transverse location of tower center is not to be confused with the tower "width" d.

[10]*Some* history-chain segments must *reverse* their direction of age change in any "pair of pants" pattern (a requirement that excludes the sector indices $T_1, \bar{T}_1, T_2, \bar{T}_2$ from material history); the sign of *physical* charge carried by the reversing segment corresponding reverses, just as in a Feynman graph.

a photon must then include at least one pre-event of zero electric charge and at least one of charge $\pm e$. Total electric-charge possibilities for charged elementary particles would then be $\pm e, \pm 2e, \pm 3e$.

Acknowledgements

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